LUNAR LEVITATION DUST INSTRUMENT FOR A LANDER: INVESTIGATING ELECTROSTATIC DUST TRANSPORT ON THE MOON

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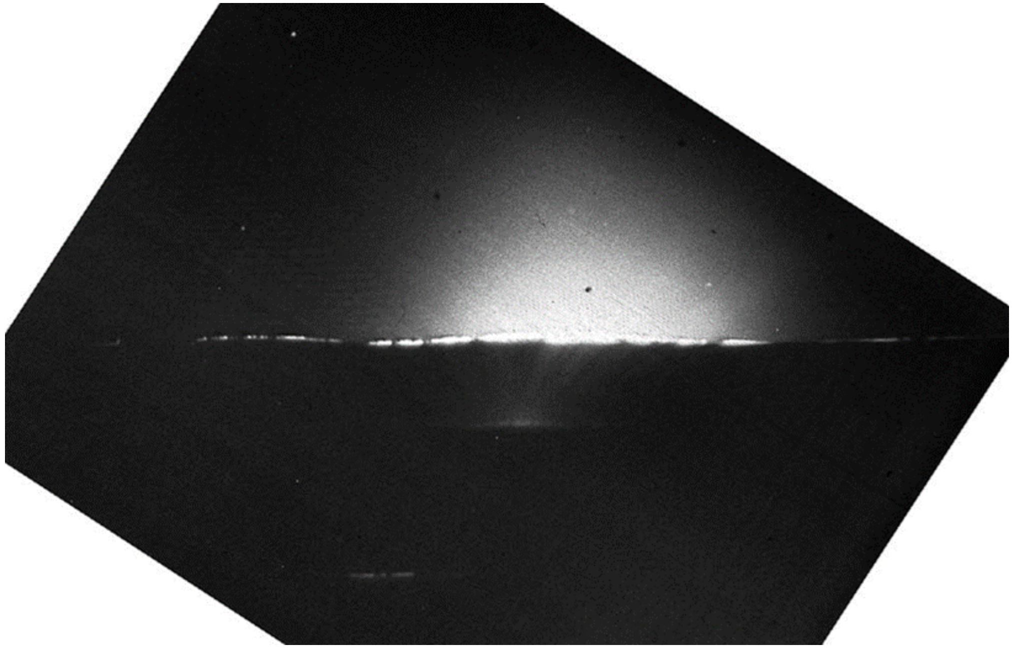
DLR

Lunar Regolith and Dust

- Lunar regolith : loose deposit of rock (Si, Fe, O_2)
- ranges from large boulders to ultrafine dust, < 1 cm in size.
- finest components < 20 micron make up Lunar dust environment
- HORIZON GLOW (HG) at the terminator by Surveyor and Apollo missions
- HG is mainly because of forward scattering of sunlight
- Dust is abrasive, sticky, health risky, technology threat

→ critical for instruments, vehicles, humans

Footprint of Buzz Aldrin in Lunar Regolith (Credits: *NASA Public Domain)*

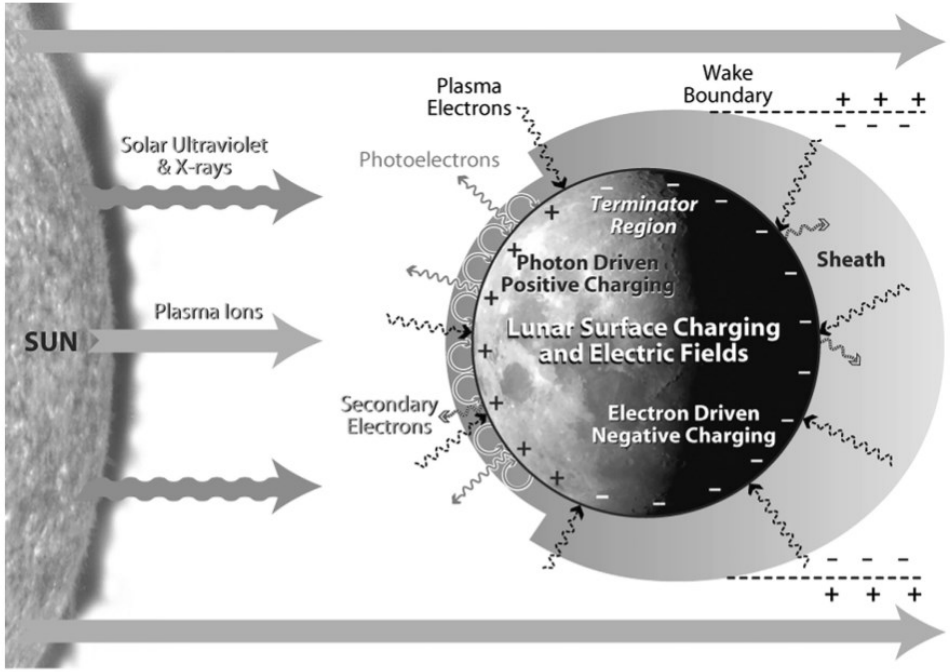


Surveyor 6 image showing a glow on the western lunar horizon after sunset (Credits: *NASA Public Domain*)

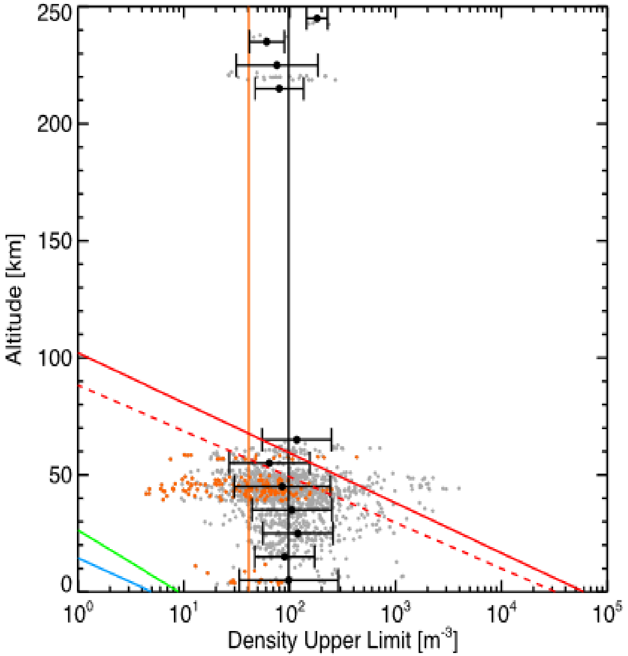
Lunar Dust: Charging Mechanisms

1. photoemission of electrons by UV rays and light X-rays
2. plasma electrons and ions
3. secondary electrons
4. electrons and ions of magnetosphere plasma (variable)

- Clementine – 1 / m^3 # density
- LDEX (LADEE) – 100 / m^3 # density
- LADEE did not find dust levitation at 20-60 km
- Chang'E-3: ~ 28 cm (no dust at higher altitudes)

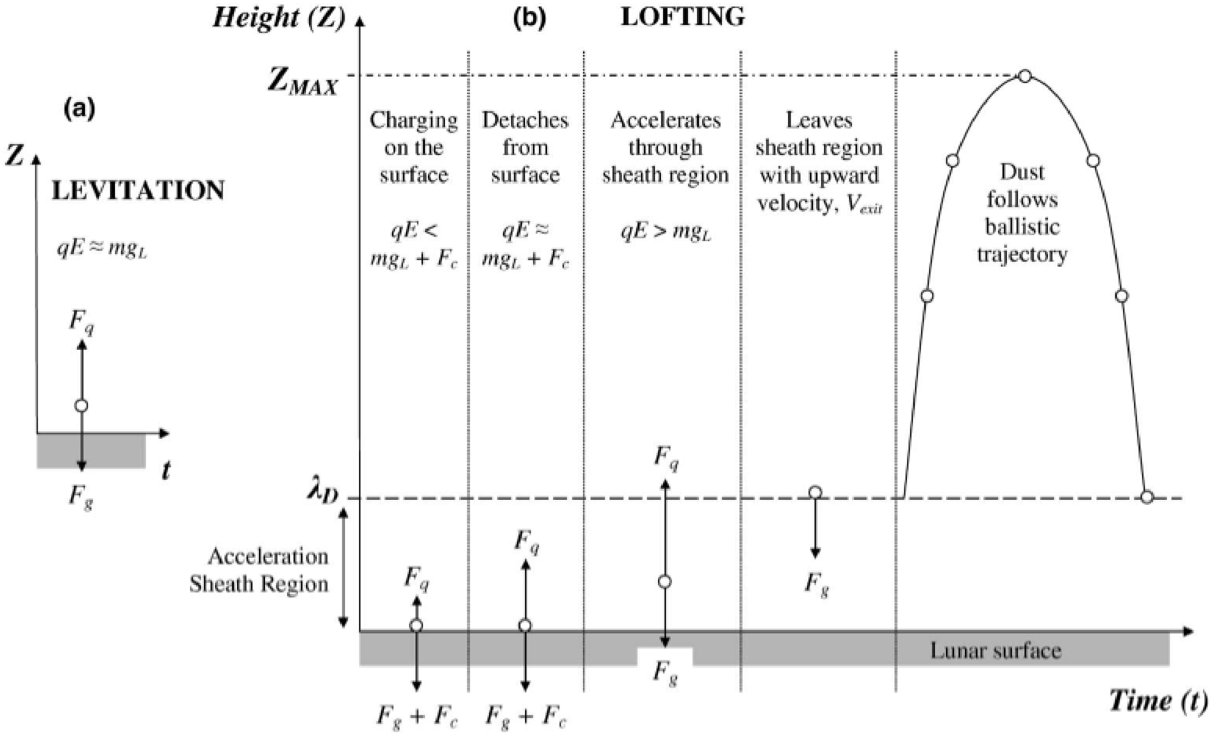


Lunar Surface Charging *(Stubbs et al. (2014))*

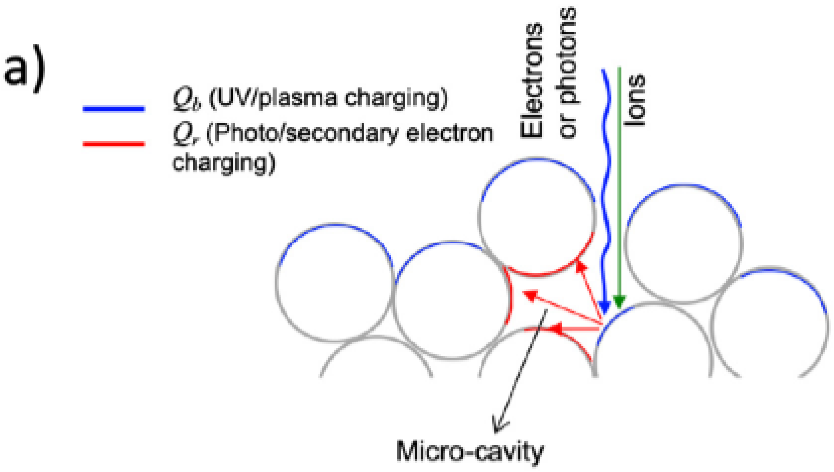


Number Density of Dust Particles measured by LDEX *(Horiyani , Szalay (2015))*

Dust Lofting Mechanism



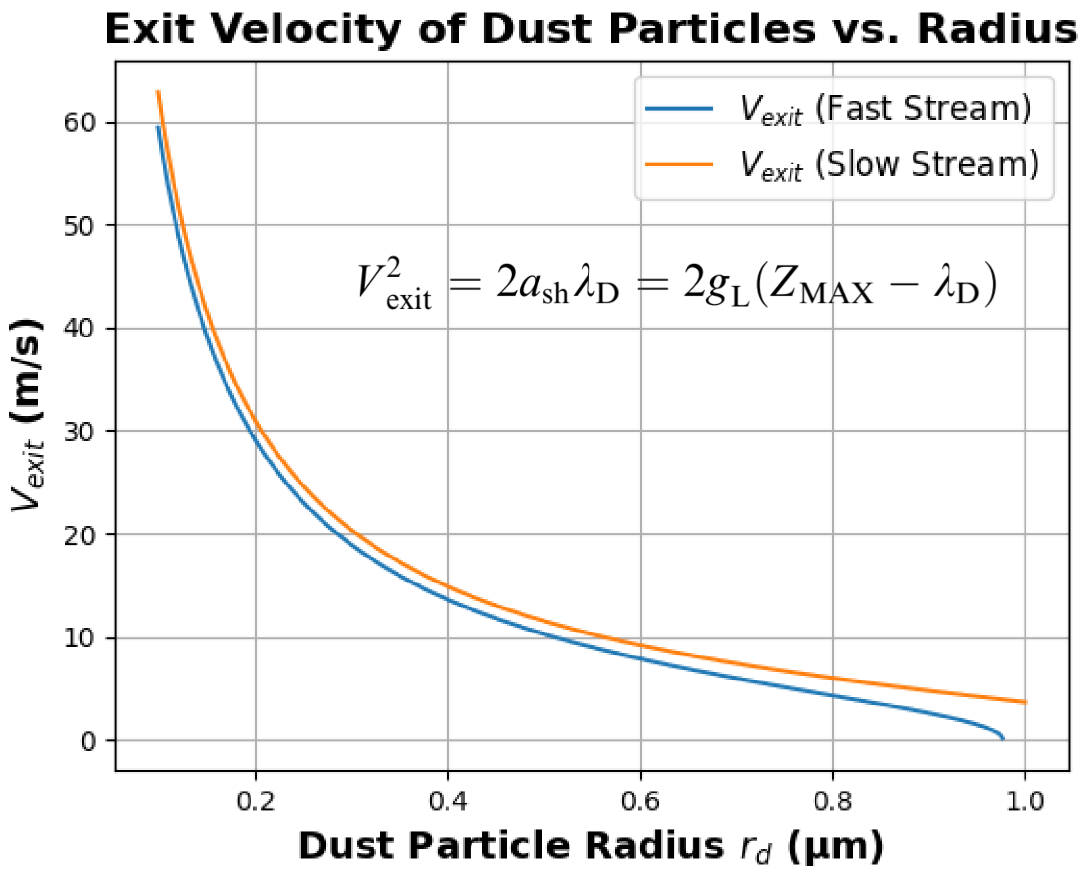
Dust fountain model (*Stubbs et al. (2006))*

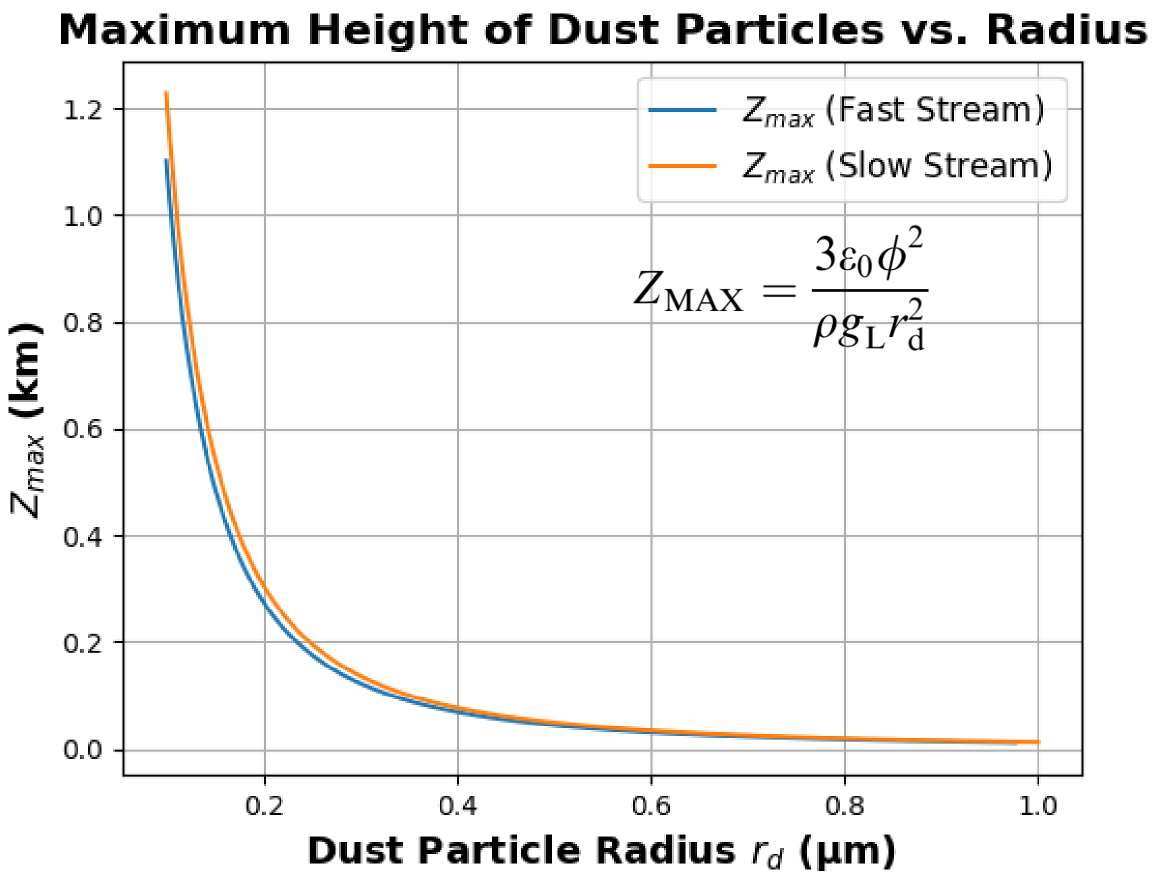


Patched charge model (*Wang et al. 2016*)

- dust fountain model explains the levitation simplified, but well enough for a 1st order assessment
- ‘Coulomb Explosions’ makes initial lift-off happen

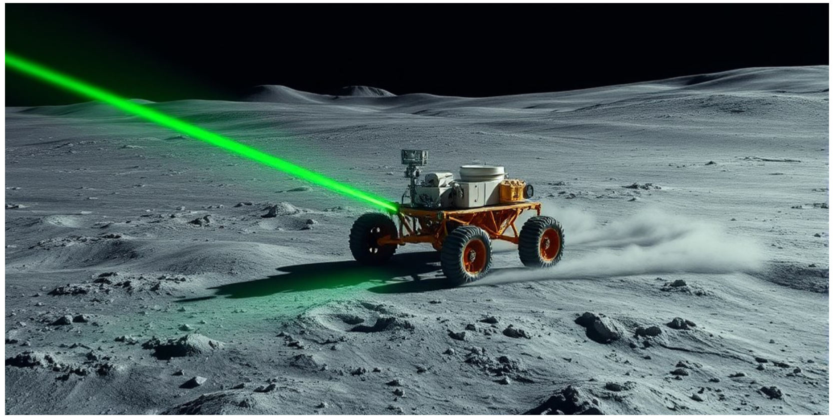
Dynamic behaviour of dust particles



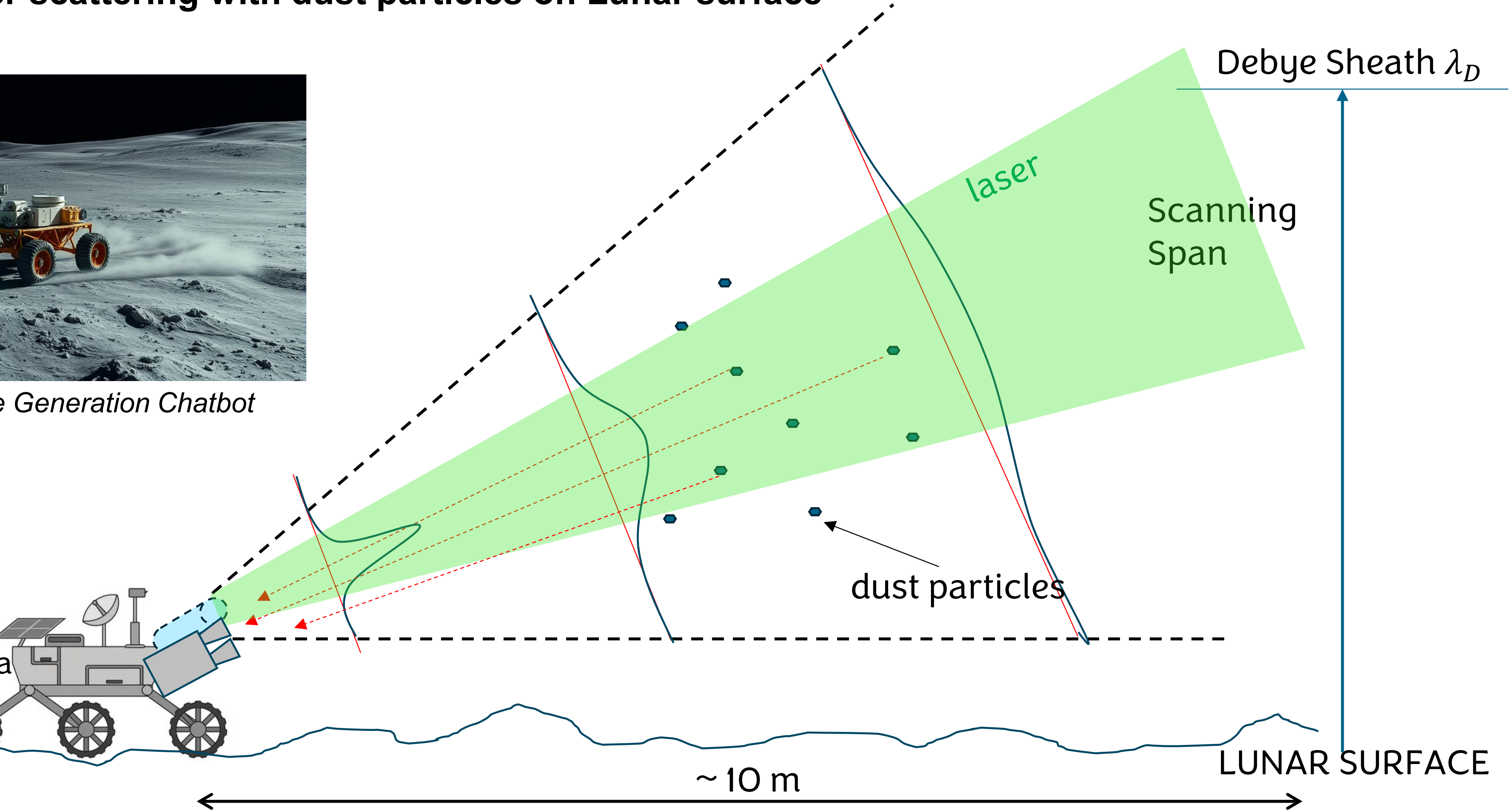


- µm sized particles are accelerated in the Debye sheet to velocities of < 10 m/s
- the heights they reach are up to 50 m, and significantly lower for particles larger than some µm

Visual of laser scattering with dust particles on Lunar surface



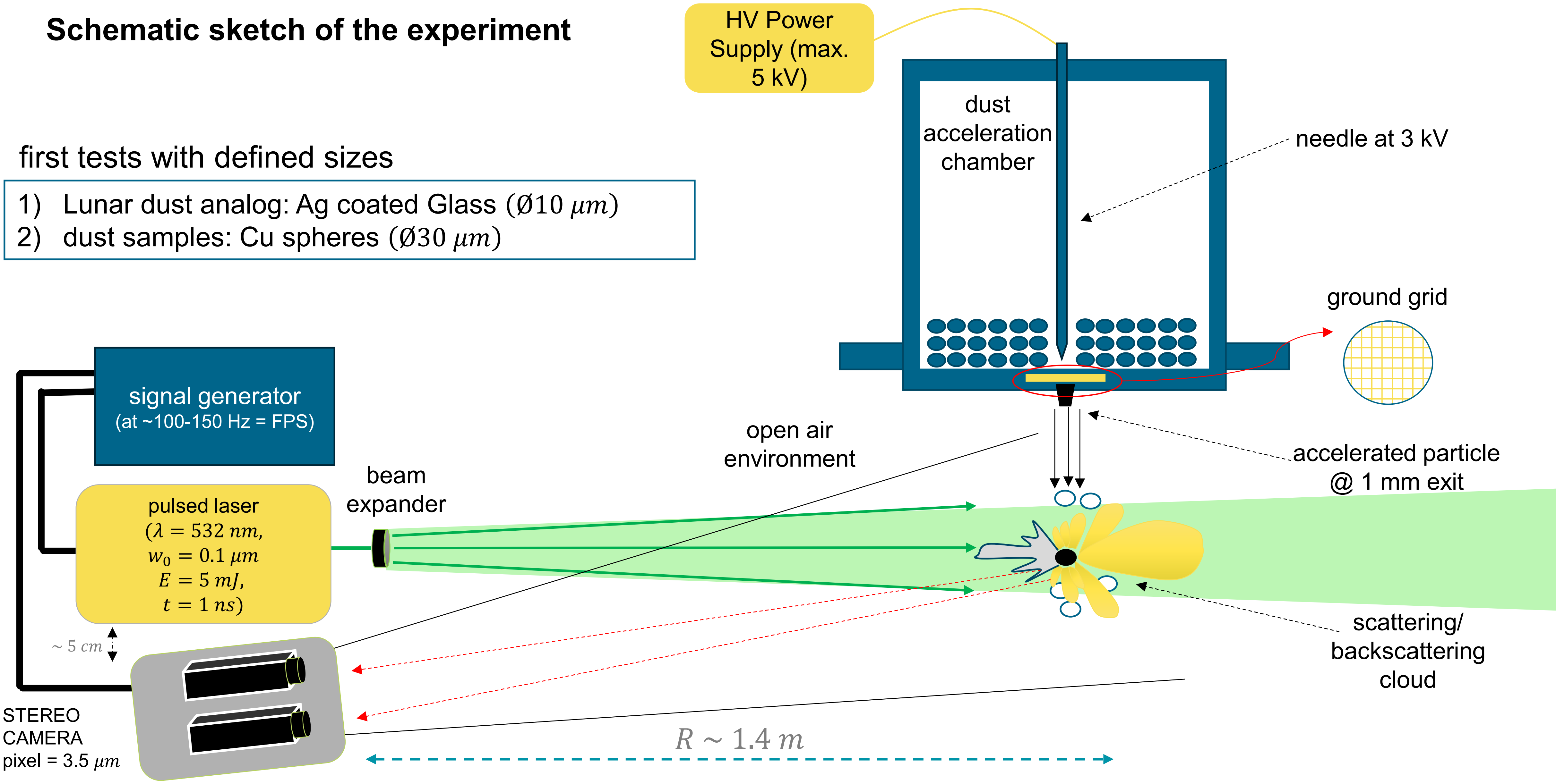
Credits: *PF-PLP Image Generation Chatbot*



Schematic sketch of the experiment

first tests with defined sizes

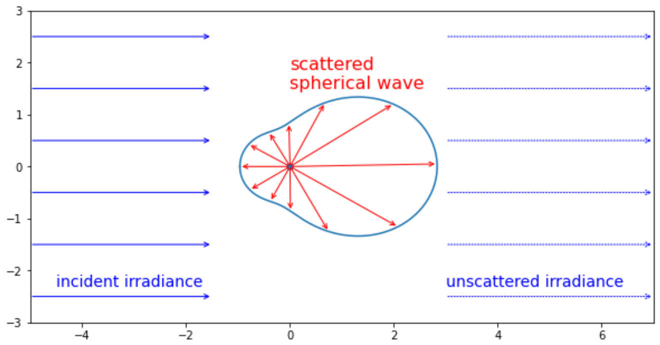
1) Lunar dust analog: Ag coated Glass $(\text{Ø}10\ \mu m)$
2) dust samples: Cu spheres $(\text{Ø}30\ \mu m)$



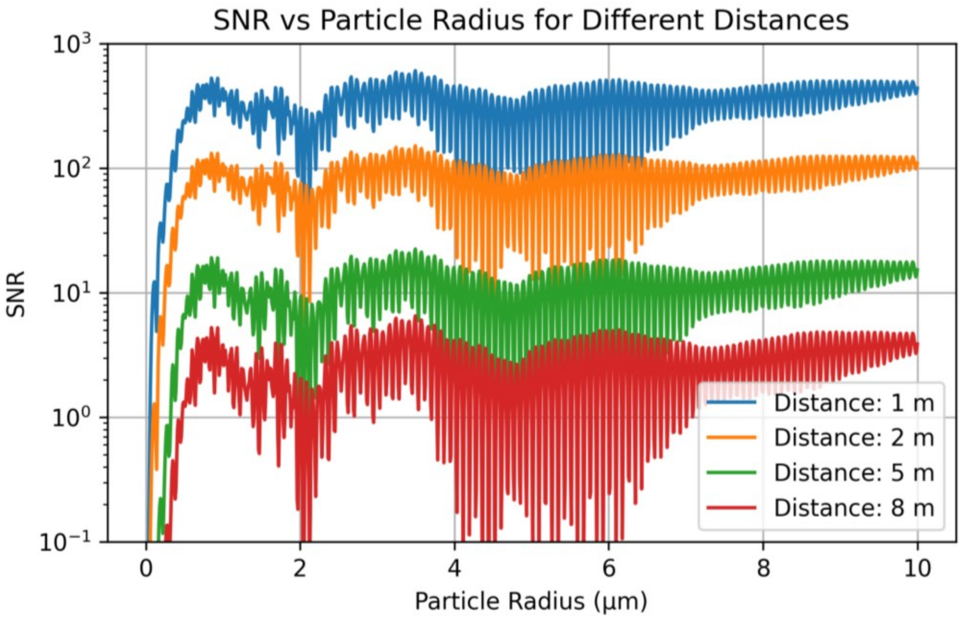
Signal Calculations

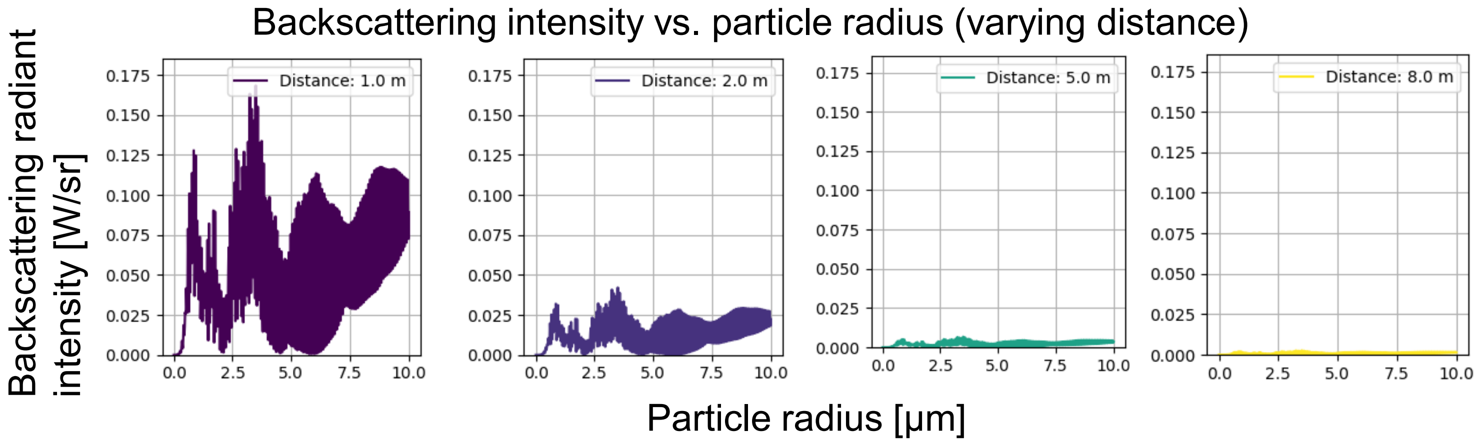
- SNR calculations were done for feasibility check
- Mie theory assumed for first assessment
- assuming a pulsed 5 mJ laser with full beam divergence of about 35 mrad
- SNR > 1 for particles larger 1 µm

Assumptions for Mie Calculations	
Refractive Index (lunar samples)	1.56 – 0.01j
Particle Radius	0.1 – 30 µm
Wavelength	532 nm
Scattering angle	-180 degree
Distance	1 – 8 m

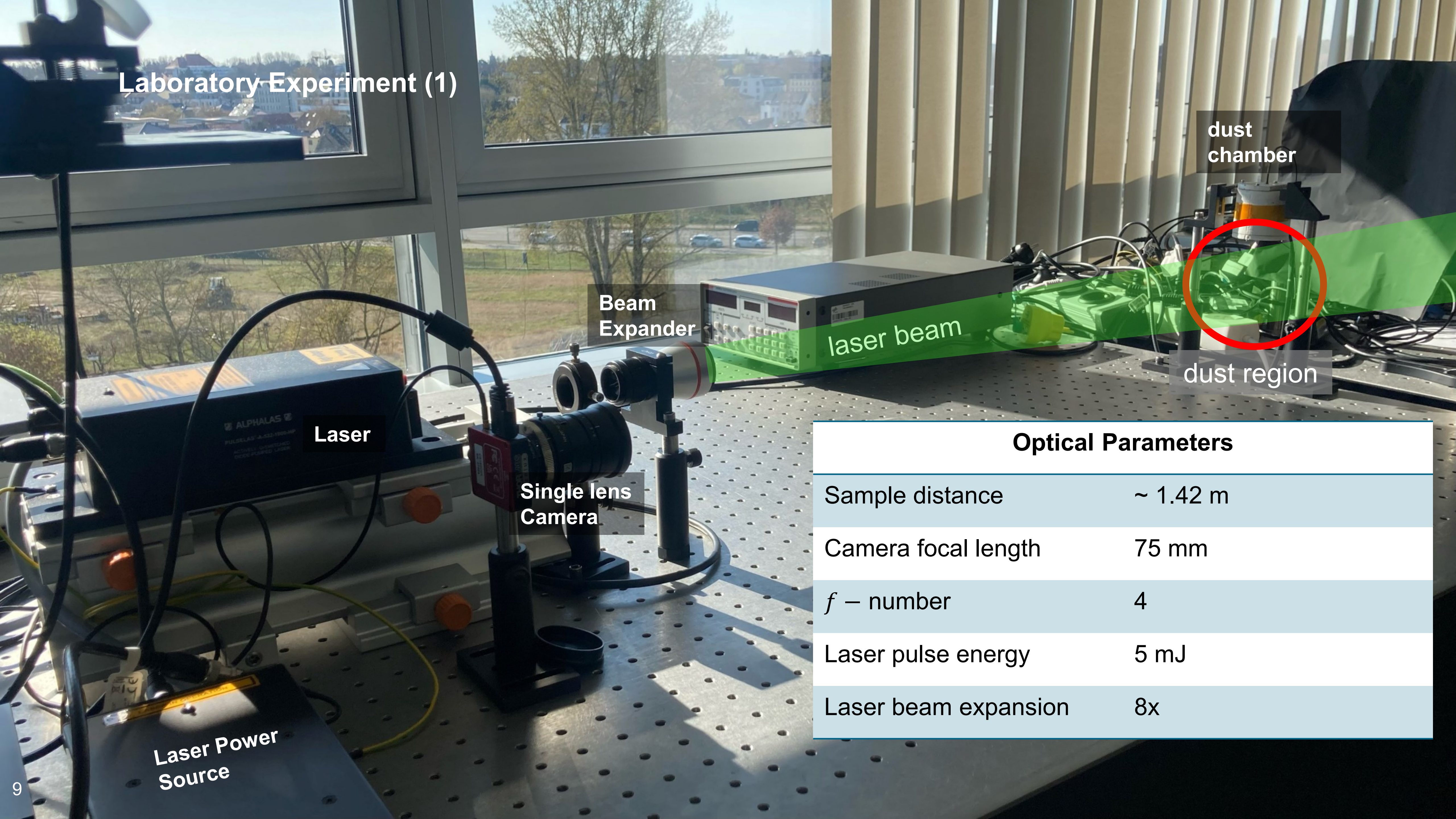


Credits: Scott Prahl/miepython



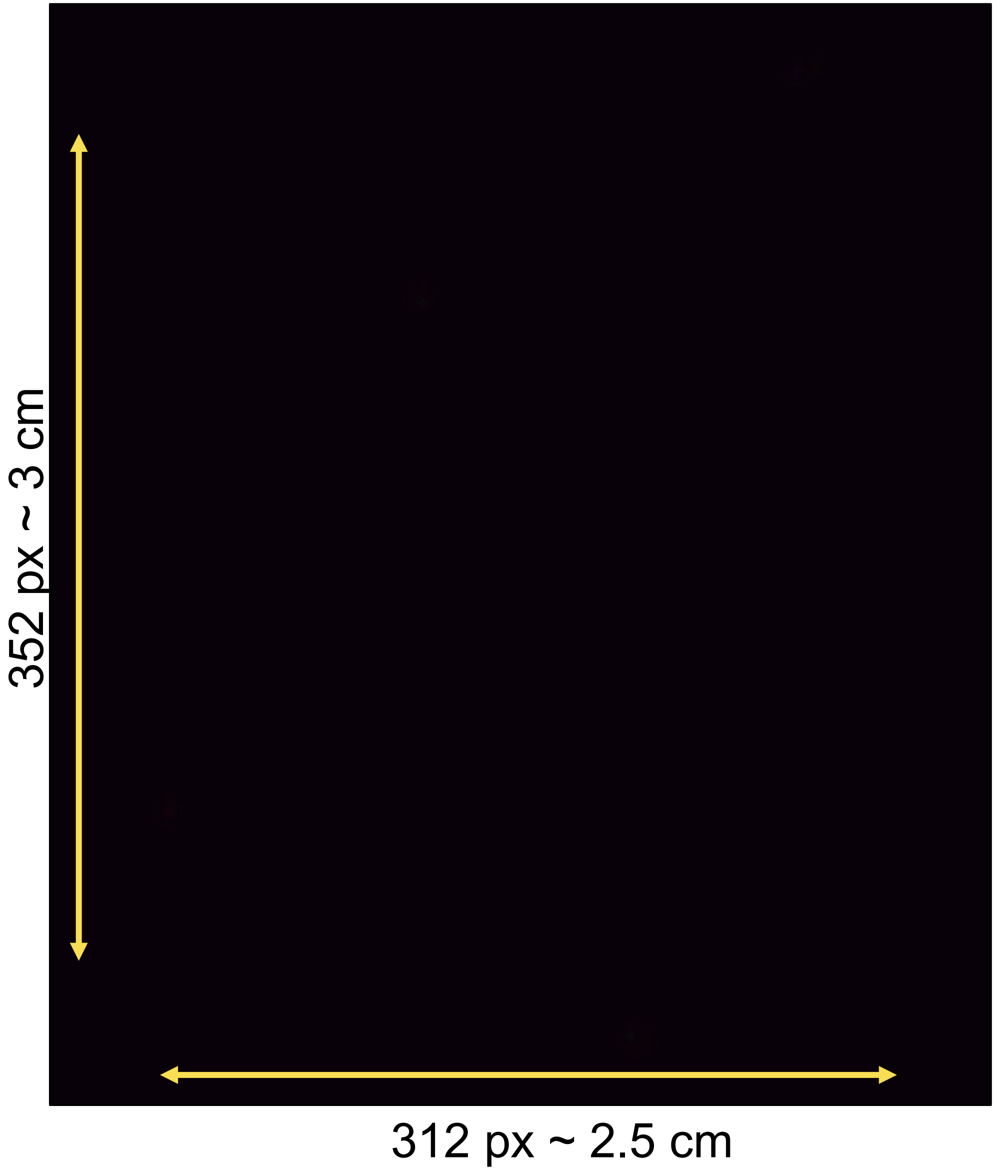


Laboratory Experiment (1)



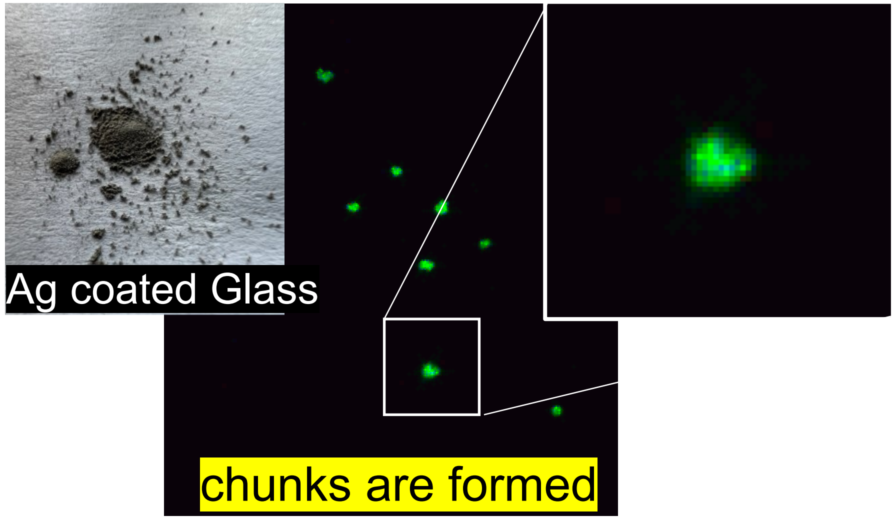
Optical Parameters	
Sample distance	~ 1.42 m
Camera focal length	75 mm
f – number	4
Laser pulse energy	5 mJ
Laser beam expansion	8x

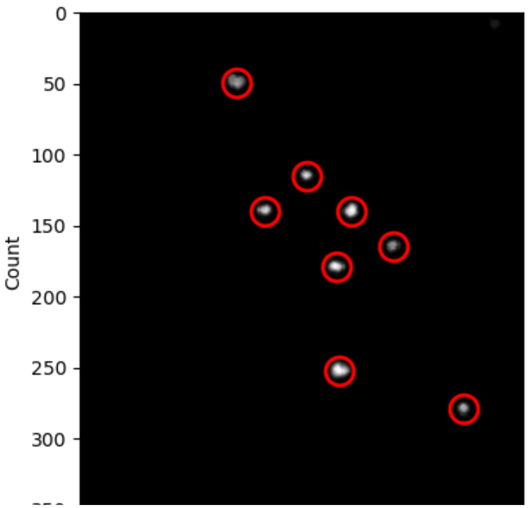
Laboratory Experiment (2)

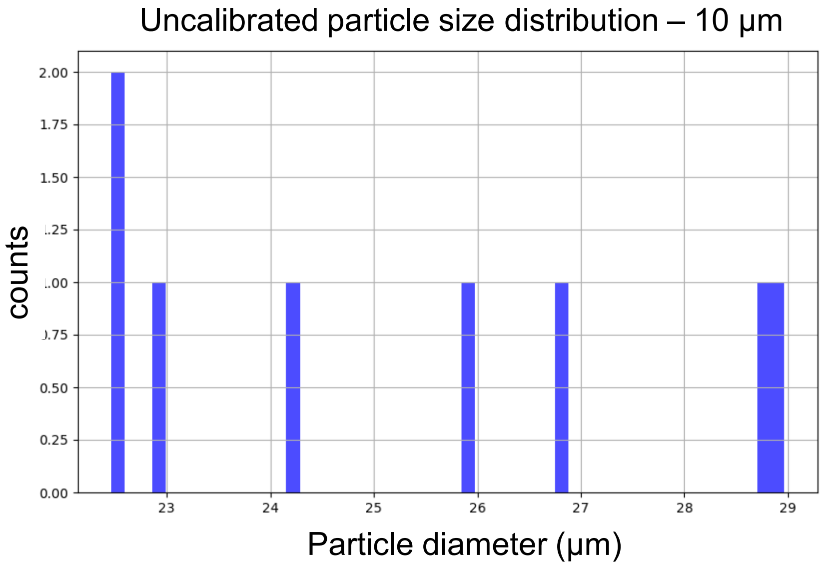


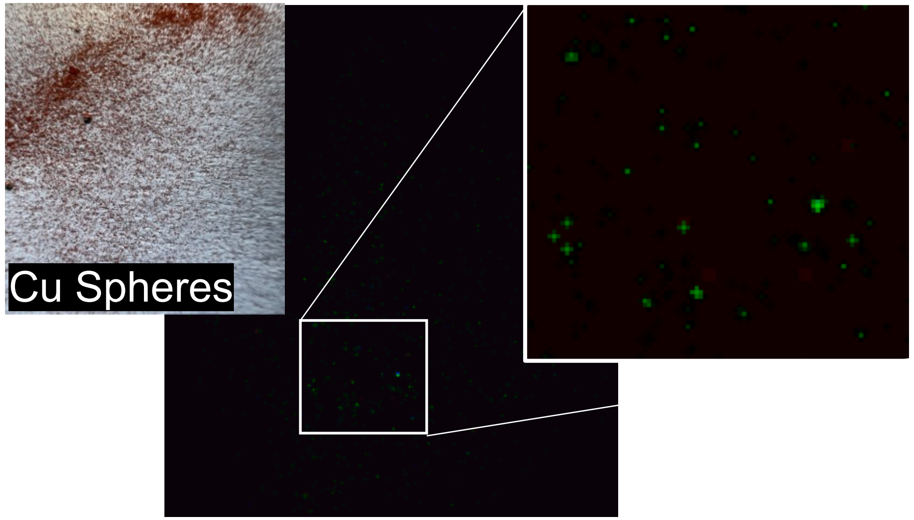
Camera settings	
Detector Resolution	1080 x 1440
ROI	312 x 352
Frames per second	100
Exposure time	1.6 ms
Gain	0
Triggering	Hardware
Pixel pitch	3.5 µm
Magnification	0.06

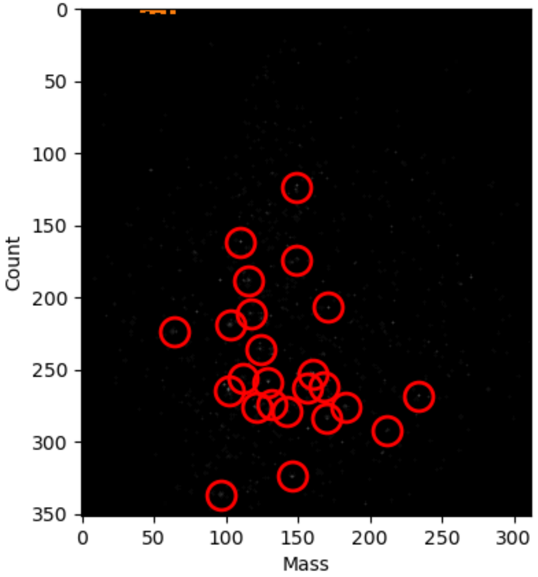
Laboratory Experiment (3)

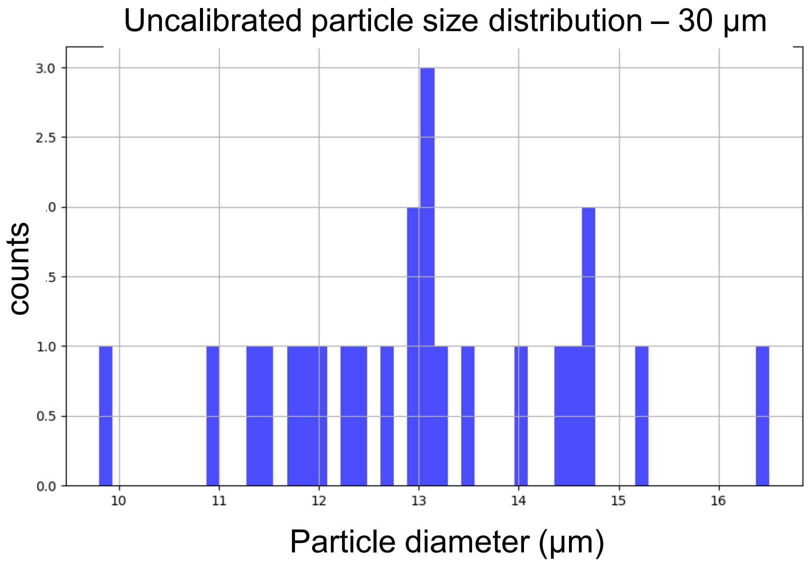








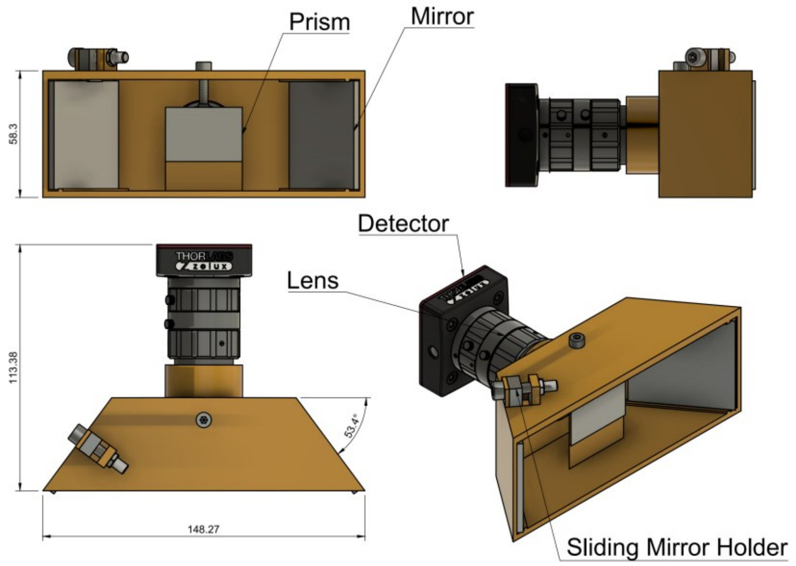




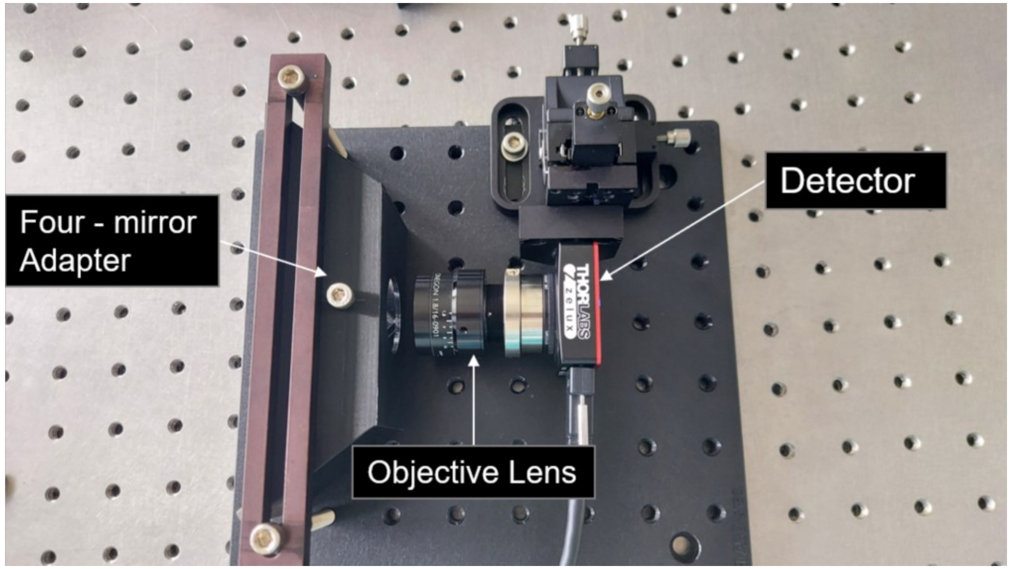
Later implementation of Stereo Camera

- implementation of stereo imaging planned

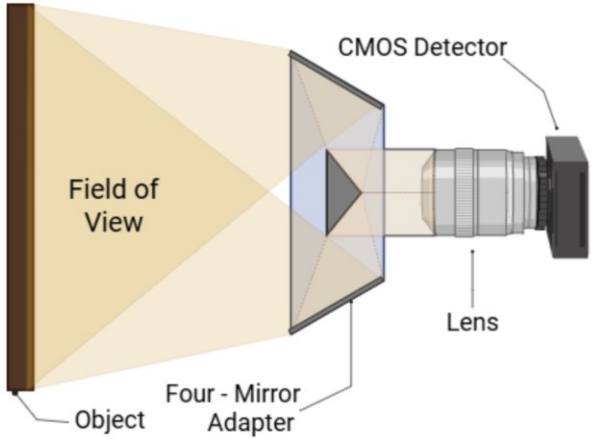
- knowledge of **position** of the particle in space (x, y, z)
- for deriving **number densities**
- for estimating **particle sizes** through **signal strength**
- for calculation of **velocity** components v_x, v_y, v_z



Credits: S. Chauhan



Credits: S. Chauhan



Conclusions & Outlook

- **Understanding lunar dust** under various charging mechanisms is essential.
- Literature and missions **show µm/sub-µm dust particles levitate to meter scales** and contribute to Horizon Glow.

- Laser scattering **successfully demonstrated dust detection**.
- Algorithm **identified** particle sizes, distributions, and densities.

- Dust chamber testing requires a more controlled approach.
- “Salt-pinching” used as an alternative test method.
- **Algorithm needs development for backscattered intensity** and detector irradiance.

- A higher FPS camera (>150 FPS) is needed to track faster particles (~4 m/s).
- More accurate **particle refractive index** data needed for model validation.
- **Correlation signal strength** with particle size.
- Conduct tests in **controlled environments** with finer dust.